RESEARCH NOTE

THE NEED FOR QUANTITATIVE SAMPLING TO CHARACTERIZE SIZE DEMOGRAPHY AND DENSITY OF FRESHWATER MUSSEL COMMUNITIES

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ABSTRACT

An accurate estimate of density of all mussels in a community, regardless of size, requires collecting total substratum samples. As part of a monitoring program on bivalves in large rivers, 0.25 m^2 quadrat total substratum samples were collected by divers at two dense beds, one in the upper Mississippi River at Prairie du Chien, Wisconsin, the other in the lower Ohio River near Olmsted, Illinois. A linear relationship existed between the cumulative number of species obtained and the logarithm of the number of quadrats sampled. Using this relationship it was estimated that 40 and 200 samples, respectively, were required to accurately assess species richness at high and low density sites in the upper Mississippi River. Because of the contagious nature of these beds, reliable density estimates for all unionid species required at least 7 to 12 quantitative samples. Dominant species were characterized by infrequent but fairly strong recent recruitment, illustrating the necessity of collecting and processing total substratum samples to obtain juveniles.

An evaluation of the condition of a mussel bed should be based upon measurements of species richness, relative abundance, density, and recruitment. Accurate determination of all of these parameters, except perhaps species richness, requires that quantitative samples of bottom material be obtained and sieved for all live mussels regardless of size. Although this approach is used in most benthic surveys, it is rarely applied in studies of mussels in large rivers. In these habitats mussels often occur in substratum too consolidated to allow quantitative sampling using devices such as Ponar, Eckman, Peterson, or Shipek dredges (Isom and Gooch, 1986). The Surber sampler (Henderson, 1949) and suction pumps (Mattice and Bosworth, 1979) have been used to quantitatively collect bivalves in shallow streams. However, the occurrence of unionids in deep water and in consolidated gravels has made quantitative studies of these communities difficult.

Brails, or crowfoot dredges, were developed by commercial fishermen and have been used to study the distribution and relative abundance of unionids in large rivers (e.g. Smith, 1898; Baker, 1903; Coker, 1918; Starret, 1971), but surveys conducted with these devices suffer numerous and variable biases (e.g. Scruggs, 1960; Krumholz *et al.*, 1970; Thiel *et al.*, 1980; Kovalak *et al.*, 1986). Semi-quantitative surveys have been performed by having divers equipped with SCUBA retrieve mussels by feeling for them within quadrats (e.g. Duncan and Thiel, 1983; Isom and Gooch, 1986; Kovalak *et al.*, 1986) or along transects (e.g. Brice and Lewis, 1979; Isom and Gooch, 1986). Search and feel methods are almost certainly biased against species characterized by small-sized animals or juveniles of species characterized by large-sized animals, but have improved our understanding of mussel distribution in large rivers relative to use of brails (e.g. Isom and Gooch, 1986; Kovalak *et al.*, 1986).

The purpose of this paper is to describe a sampling approach that utilizes quantitative substratum removal to accurately assess size demography and density of unionids in large river habitats. These studies were conducted as part of a monitoring program on population and community structure of bivalves at prominent beds to assess impacts of water resource development.

STUDY SITES

Studies were conducted at two mussel beds, one

located in the east channel of the upper Mississippi River near Prairie du Chien, Wisconsin (RM 636) and the other in the lower Ohio River near Olmstead, Illinois (RM 967). Both beds were several km long, at least 300 m wide, and were found in stable substratum. Sampling sites were in fairly deep water (4-6 m at typical low water levels in early fall), and located a minimum of 100 m from the periphery of the bed. Mussel beds were identified from published information (e.g. Havlik and Stansbery, 1978, for the site on the upper Mississippi River and Williams, 1969, for the site on the lower Ohio River). The approximate size of each bed, and location of sites was determined by a diver performing a general reconnaissance. A mussel bed was defined as a contiguous area of stable substratum where densities were at least 10 individuals per m^2.

In the east channel of the Mississippi River in October 1984, 10 samples were taken at each of five sites that were separated by about 1 km. In July 1985, 30 samples were taken at each of two sites that consisted of three subsites (see Hurlbert, 1984) sampled 10 times each. Preliminary sampling at these and other beds indicated that at least ten samples would be required to estimate species richness and total mussel density. Study sites were separated by a distance of 0.5 to 1.5 km; subsites were within 50 m of each other. In addition, a pair of quadrats were taken every 1.2 m along a 14.4 m transect in a dense part of the bed.

At the mussel bed in the Ohio River, four sites that were about 50 m apart were sampled six times in September 1983. In October 1985 a single site was sampled 13 times, and in September 1986, eight sites were sampled eight times and one site was sampled four times. The 1983 and 1985 surveys were conducted in the upstream half of the bed; the 1986 survey was conducted near the downstream limit of the bed.

METHODS

At each site in a bed, a diver collected samples from within an aluminum 0.25 m^2 quadrat that was positioned in a haphazard manner near an identifying buoy. The diver transferred all substratum, which included sand, gravel, shells, and live organisms, from each quadrat into a 20 *l* bucket. In consolidated gravel, digging tools were needed to remove all material to a depth of 10-15 cm. Collection of a single sample required 5-15 min. The bucket was pulled or winched to the surface and transported to shore, where collected material was washed through a graduated series of sieves. The finest sieve had a mesh aperture of 4 mm. Material retained on each screen was examined for live mussels; 5-15 min were required to wash and pick each sample. Collected mussels were taken to a mobile laboratory, identified by species, and their shell lengths measured to the nearest 0.1 mm. Individuals not needed for voucher specimens were returned to the river.

Although the dive crew consisted of 3 - 4 individuals, only a single diver worked a site at a time. Support personnel consisted of 4 - 6 individuals that helped position boats and transport and process samples. Depending upon logistics and experience of personnel, 10 - 30 samples were collected and processed to completion each day.

RESULTS

SPECIES RICHNESS AND RELATIVE ABUNDANCE.

The cumulative number of species obtained at any site was a linear function of the logarithm of the number of quadrats sampled. This relationship is portrayed for representative high and low density sites located in beds in the Ohio and Mississippi rivers (Fig. 1). The dashed lines in figure 1

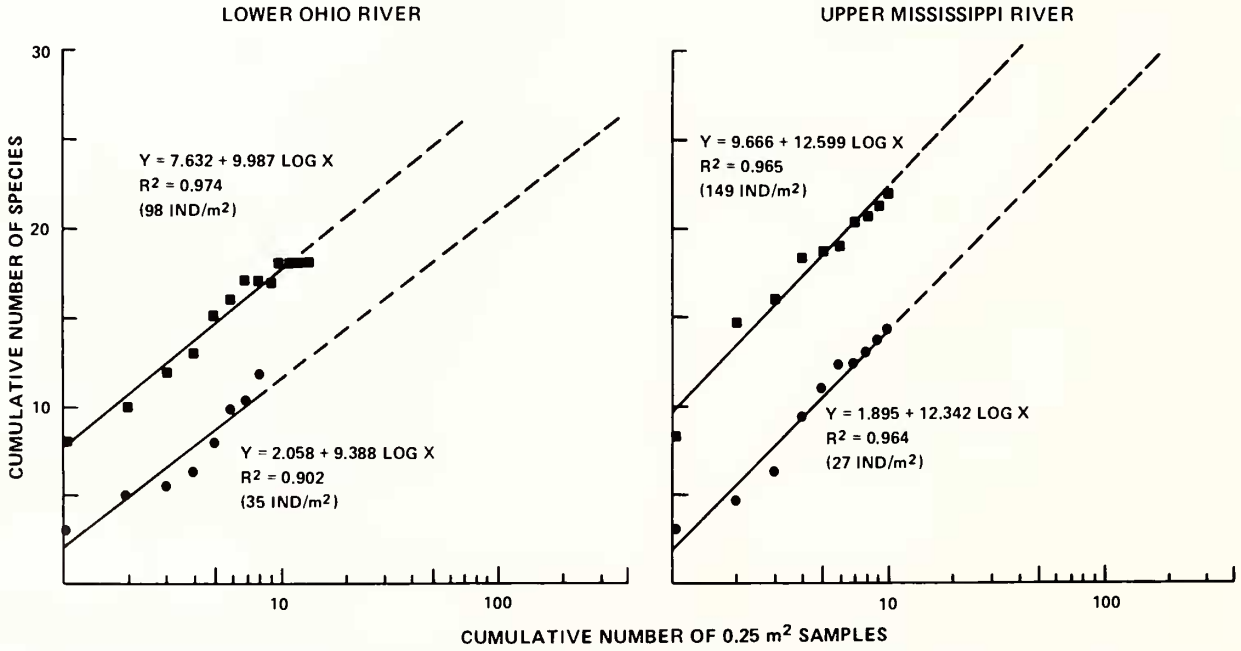

Fig. 1. Cumulative number of species in relation to number of quadrat samples collected in the Ohio and upper Mississippi rivers.

extend the number of samples beyond that which was collected in these surveys to a value necessary to obtain all species reported to exist in the beds in the Ohio (Miller *et al.*, 1986) and Mississippi rivers (Havlik and Stansbery, 1978). Extensions of these lines are not statistically valid in a strict sense. However, such extensions are instructive and supported by the ubiquity of relationships between estimates of species richness and the number of samples collected (McNaughton and Wolf, 1973). These relationships depict the diminishing rate of addition of new species as more samples are taken. For example, at a high density site in the Ohio River, 15, 21, 24, and 25 species were yielded by 10, 20, 40, and 60 samples, respectively. At a dense site in the Mississippi River, all species known from this reach of the river were collected with 40 samples; however, approximately 200 samples would be needed at the low density site to obtain all species present (Fig. 1).

A large number of quadrats must be sampled to obtain all species in both beds because most mussels are locally uncommon. Both beds were heavily dominated by a single unionid species. For example, *Amblema plicata* (Say) comprised 54.3% of the east channel community in the upper Mississippi River in 1985 and *Fusconaia ebena* (Lea) represented 66.7% of all native unionids in the Ohio River in 1985. Of the 29 species collected in the upper Mississippi River in 1985, 16 accounted for less than 1% of the community. *Lampsilis higginsi* (Lea), a species on the Federal list of endangered species, ranked 17th on the list and comprised 0.61 and 0.58% of the community in 1984 and 1985, respectively. Of the 23 species collected in the Ohio River during the 1985 survey, 11 accounted for less than 1% of all native unionids. *Plethobasus cooperianus* (Lea), a federally-listed endangered species was collected in this bed using qualitative techniques (Miller *et al.*, 1986), but was not obtained in quadrat samples during any year.

DENSITY

In the upper Mississippi River, the average density of all unionid species at the five sites sampled in 1984 and the two sites (consisting of three subsites) sampled in 1985 ranged from 22 ± 20 to 202 ± 36 individuals per m^2 (± standard deviation, N = 10 at each site or subsite). In the lower Ohio River, densities ranged from 47 ± 24 to 80 ± 20 (N = 6) in 1983, and 102 ± 30 (N = 13) in 1985, and 9 ± 3 to 31 ± 6 individuals per m^2 (N = 8 for eight sites and N = 4 for one site) in 1986.

A further illustration of the contagious nature of these molluscan communities is shown by the results of sampling along a transect within the bed in the Mississippi River (Fig. 2). The spatial heterogeneity of the bed directly affects the number of samples required to accurately estimate mussel density with a defined level of accuracy and precision. The number of samples required to estimate mussel density was determined by treating a set of replicate samples within a site as a pilot survey. To determine the number of quadrats necessary to achieve a desired precision of total mussel density a procedure from Green (1979:41) was used. This requires making an estimate of the mean and standard deviation of

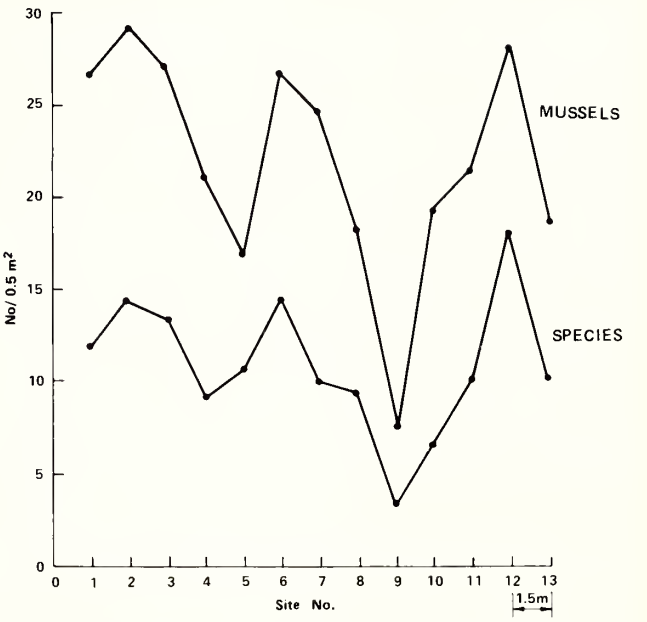

Fig. 2. Total individuals and species richness (pool for two 0.25 m^2 quadrats) from a transect in the upper Mississippi River.

the population from preliminary sampling. The number of samples necessary to achieve a desired estimate of precision is a function of the variance of the pilot sample. For each of the 11 site-specific surveys in the upper Mississippi River we computed the number of samples necessary to estimate the average density of all mussels within either 10 or 30% of the actual average density with a 5% probability of being incorrect. We found that from 1.4 to 37.5 (mean = 12.2) samples were required to be within 30% and from 12.9 to 246.5 (mean = 109.8) samples were required to estimate to within 10% of the actual average density of all unionids at the 11 sites. The coefficient of variation of density estimates was lower at sites in the Ohio River than those in the upper Mississippi River. From 1.7 to 15.9 (mean = 6.2) samples were required to be within 30%, and from 19.2 to 143.0 (mean = 55.9) samples were needed to estimate to within 10% of the average density for the 14 sites in the lower Ohio River.

SIZE DEMOGRAPHY

The most useful aspect of quantitative sampling was the detection of patterns in population recruitment for *Amblema plicata* in the Mississippi River and *Fusconaia ebena* in the Ohio River. The dominant species in both beds showed evidence of tremendous annual variation in recruitment strength. Mature females of both species produce glochidia each year for many years during their reproductive life span, and survival of glochidia through metamorphosis and settlement is contingent upon a number of abiotic and biotic variables. Thus, large annual variations in recruitment should be expected in such populations.

Shell length frequency histograms for *Amblema plicata* in the Mississippi River indicate that recruitment success was

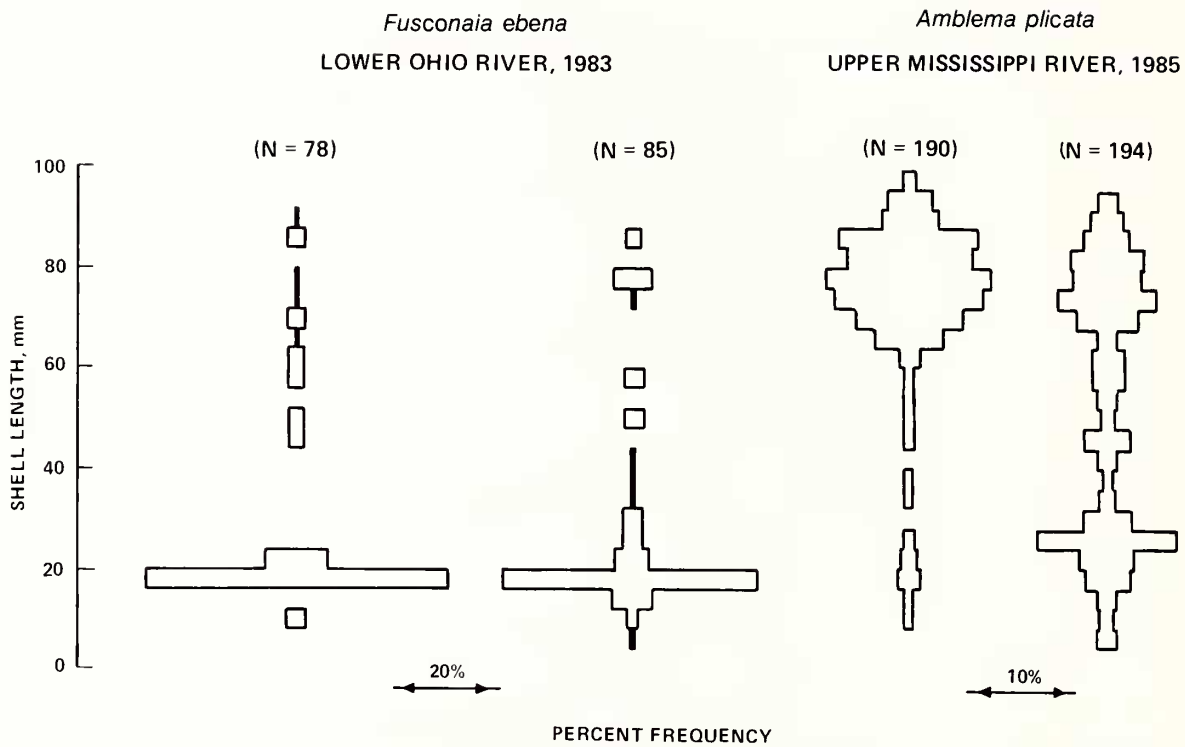

Fig. 3. Representative length-frequency histograms for *Fusconaia ebena* at two sites in the Ohio River in 1983 and *Amblema plicata* at two sites in the Mississippi River in 1984.

low for year classes represented by mussels between 40 and 60 mm in 1984 (Fig. 3). It is unlikely that selective mortality of these size classes occurred in the post-settlement stage of the life cycle. Also, recruitment exhibited spatial variability within the mussel bed. Although the sites in the Mississippi River depicted in figure 3 were less than 1 km apart, recruitment rates were not uniform throughout the mussel bed.

Intersite differences in patterns of size demography were not detected for *Fusconaia ebena* in the Ohio River (Fig. 3). However, evidence of annual variation in recruitment was more striking for *F. ebena* in the Ohio River (Fig. 3). In this population a single year class (probably 1982), represented by mussels 16-20 mm long, accounted for 70% of all individuals of this species collected in 1983. This same year class remained a dominant feature of the size demography of this population when assessed again in 1985 and 1986 (Fig. 4, cohort centered at 29 mm in 1985 and at 36 mm in 1986). Strong recruitment was not observed for any year class since 1982.

DISCUSSION

The areas studied in the upper Mississippi River near Prairie du Chien, Wisconsin and the lower Ohio River near Olmsted, Illinois are among the most dense and rich mussel beds in these two rivers (Havlik and Stansbery, 1978; Miller *et al.*, 1986). Rigorous quantitative sampling at both beds revealed common features of community and population structure. Both communities are marked by heavy dominance

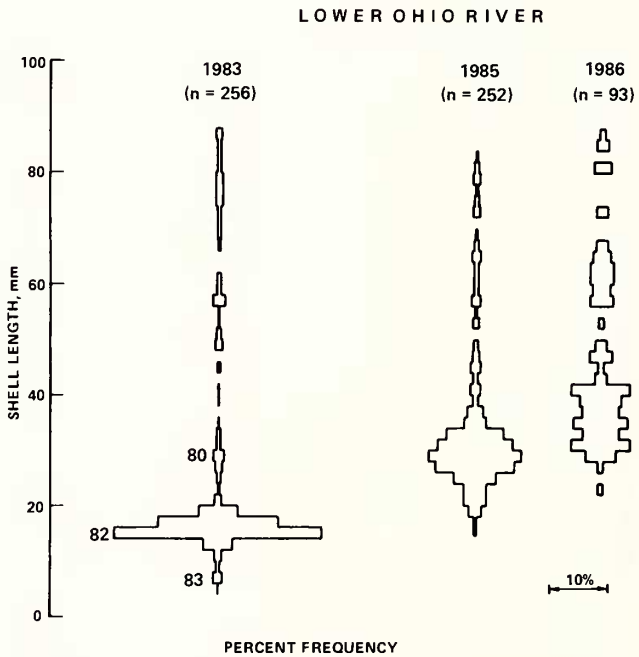

Fig. 4. Annual variation in recruitment for *Fusconaia ebena* in the lower Ohio River in 1983, 1985, and 1986.

by a single species and a large number of uncommon species. This same pattern is observed in most natural communities (e.g. Hughes, 1986). Based upon results of these studies,

mussels in large rivers are no exception to this general rule.

Quantitative samples are required for unbiased estimates of the relative abundance of species. A consequence of the local rarity of many unionids is that a large number of quantitative samples are required to obtain all species at a site (see also Kovalak *et al.*, 1986). A combination of qualitative and quantitative sampling methods is the most efficient way to completely assess community composition. Qualitative surveys facilitate estimation of species richness, and quantitative surveys are required for estimation of relative species abundance.

Density of mussels is estimated with fewer samples than species richness and relative abundance. Based on our results, seven to twelve quadrat samples were sufficient to estimate the average density within 30% of the actual average density at a site with a 5% probability of being incorrect. As these statistics demonstrate, intersite variation in average density and the coefficient of variation of density estimates can be substantial. This is a direct consequence of the contagious nature of these communities and illustrates the need for a study design which includes adequate number of sites and replicates. Intrasite variation could be reduced by collecting individual samples within cells of a large (4m x 4m) 16-celled PVC grid secured to the bottom with pins. This procedure could help to eliminate diver bias and could reduce the coefficient of variation of estimates made of particularly contagious distributions.

Annual and intersite variation in recruitment was evident in both mussel beds. Intersite variation in patterns of size demography, like intersite variation in density, argues for sampling replicate sites. Annual variation in recruitment of dominant mussels, while evident in both beds, was particularly striking for *Fusconaia ebena* in the lower Ohio River. The size demography of this species was such that a single year class will remain a dominant feature of the size structure of this population for years hence.

Most riverine unionids have a long life span, take several years to mature, and appear to have great annual variation in recruitment success. These organisms are especially sensitive to commercial fishing and development of water resource projects. Regulation of commercial harvests and protection of habitat must be based on knowledge of population and community demographics. Currently we are conducting annual surveys at important mussel beds to monitor long-term trends in these parameters. However, most mussel studies in large rivers have not been sufficiently quantitative to elucidate important aspects of the biology of these invertebrates. Judgments on the condition of freshwater bivalves in large rivers should be based on quantitative substratum sampling that enables accurate determination of relative abundance, density, recruitment, growth, and mortality.

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